Department of Energy
Washington, DC 20585
December 15, 2000

The Honorable Floyd Spence
Chairman
Committee on Armed Services
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

In accordance with the requirements of Section 3142 of the *Floyd D. Spence National Defense Act for Fiscal Year 2001 (Public Law 106-398),* submitted herewith is the report requested on the River Protection Project (formally known as the Tank Waste Remediation System), located at the Hanford Reservation, Richland, Washington. The Office of River Protection prepared this report in cooperation with my Office of Science and Technology. As you may know, the waste treatment plant privatization contract with BNFL Inc. was terminated in May 2000. On December 11, 2000, a new cost-plus-incentive fee contract was awarded to Bechtel-Washington to design, construct, and commission the waste treatment plant. This report reflects current project planning; however, it will be updated after the new contractor submits its plans and schedule for the waste treatment plant. At that time we will also be in a better position to extend the plans for the first waste treatment phase to the balance of the mission.

The Office of River Protection was established at the direction of Congress in 1998 to manage the River Protection Project. Since then, significant management improvements and progress have taken place. The Office Manager has full responsibility and authority for managing all aspects of the River Protection Project. The Office budget, location, and identity are now separate from the Richland Operations Office, and the Office Manager has been delegated authority for contracting, financial management, safety, and general program management equivalent to other DOE Operations Offices. Several experienced managers and staff with critical skills have been added to the Office and additional staff positions have been authorized. Having the Office Manager report directly to the Assistant Secretary for Environmental Management provides direct access to senior Department officials.

The Department is strongly committed to putting in place the means to treat and dispose of the high-level waste at Hanford as safely, cost effectively, and expeditiously as possible. We appreciate your Committee's strong support of this important environmental initiative.

If you have further questions, please contact me or have a member of your staff contact Mr. David Berick, Deputy Assistant Secretary for House Liaison, at (202) 586-5468,.

Sincerely,

Carolyn L. Huntoon

Carolyn L. Huntoon
Assistant Secretary for
Environmental Management

Enclosure

cc:
The Honorable Ike Skelton
Ranking Minority Member

Office of River Protection

Response to Requirement for Report to Congress

Under Floyd D. Spence National Defense Authorization

Act for Fiscal Year 2001

December 2000

Response to Requirement for Report to Congress

Under Floyd D. Spence National Defense Authorization

Act for Fiscal Year 2001

Approved by: ______________________ Date: 12/5/00
Harry L. Boston
Acting Manager,
Office of River Protection

Executive Summary

This report to Congress on the River Protection Project (formally known as the Tank Waste Remediation System) responds to the requirement contained in Section 3142 of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001. The Act requires a description of the U.S. Department of Energy's (DOE's) proposed plan, schedule, cost estimate, alternatives, and technology development approach for treating and immobilizing the high-level radioactive waste at the Hanford Site in Washington State.

Background

Approximately 53 million gallons of highly radioactive wastes are stored in 177 underground tanks, including 149 older single-shell tanks, at the Hanford Site in Washington State. That waste, which was derived from production of plutonium for the nation's nuclear defense program, has been accumulating at Hanford since 1944. The waste poses a serious safety concern to the public and to the environment. Since most of the single-shell tanks have exceeded their design life, that risk is growing. Sixty-seven of the single-shell tanks are known to have leaked an estimated one million gallons of waste to the surrounding soil.

In 1998, Congress established the Office of River Protection (ORP) to manage the retrieval, treatment, and disposal of the Hanford tank waste, and then to close the tanks in compliance with the Tri-Party Agreement between DOE, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology. This must be done to protect the Columbia River, the surrounding communities, and the economic future of the region.

Since 1998, ORP has made excellent strides on improving safety, while reducing the risks posed by the stored tank waste. ORP has also made good progress in preparing to retrieve and treat the waste, including testing and evaluating the technologies to be used.

Initial Plans and Technology

The plan to treat the tank waste is divided into two phases with 10 percent of the waste mass containing 25 percent of the radioactivity treated in Phase 1 with the balance of mission to follow. Phased implementation was chosen so that waste treatment would start with robust, demonstrated technology. The phased approach provides flexibility to make changes in the future as new information and technologies emerge.

The treatment plan is to separate the waste into high-level waste and low-activity waste portions and then to immobilize both portions in glass waste forms for disposal. This plan and the technologies selected meet regulatory requirements, public expectations, and are the best available for immobilizing these wastes. Testing on actual waste and operating a pilot-scale melter have demonstrated that the technology will meet or exceed requirements. The waste to be treated in Phase 1 has been sampled and analyzed, and meets the WTP feed specifications.

The WTP has the capacity to process the Phase 1 waste by 2018. Requirements to complete the full mission were carefully considered, and provisions for future expansion capacity are provided that would enable completing the mission within the WTP design life. Decisions on future expansion capacity are deferred until there is some Phase 1 operating experience.

Treatment of Remaining Tank Waste

The plan for treating the waste remaining after Phase 1 is to expand the WTP capacity and continue its operation. Information gained from operating the WTP and investments in science and technology during Phase 1 will be used to improve the performance, reliability, and capacity of the plant.

The technologies used in the Phase 1 plant will treat more than 90 percent of the remaining types of waste. Waste sampling and analyses have provided a sound basis for estimating the quantity of 25 chemicals and 46 radionuclides that make up more than 99 percent of all the tank waste. As sampling of all tanks continues, some difficult to treat wastes may be encountered. Tanks with waste components that are difficult to treat or limit the amount that can be put in the glass will be blended with waste from other tanks to dilute the effect of those components. New technologies are also likely to emerge over the next 15 years that will provide better treatment methods for these kinds of waste. The goal is to reduce risk to the workers, public, and the environment while maximizing the value of the taxpayers' investment in clean up.

Technology Development

From the outset of this clean up mission, DOE has been investing in the technologies selected for the WTP and continues to develop, test, and evaluate alternative technologies. The new WTP contractor will have a technology development program. The contract includes incentives to improve the reference technology and bring forth alternatives that would improve WTP performance.

The Office of River Protection has partnered with the Office of Science and Technology to fully consider technology alternatives that can be applied during Phase 1 and to the remaining waste. These include better radionuclide and chemical separation processes, higher temperature melters, higher capacity and longer life melters, different glass formulations, and new vitrification technology.

The WTP is being designed to accommodate installation of new technology as it emerges in the future. With these design features and the ongoing technology development program, the Office of River Protection is confident the Hanford tank clean up mission can be completed in a cost effective manner.

Response to Requirement for Report to Congress Under Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001

Introduction

This report responds to the requirement contained in Section 3142 of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001 for a report to Congress. It describes the U.S. Department of Energy's (DOE's) current plan for carrying out Hanford's River Protection Project, which encompasses retrieving, treating, immobilizing, storing, and disposing of the high-level radioactive waste contained in Hanford's underground storage tanks. Ultimately DOE will close the tanks and the processing, storage and disposal facilities. The River Protection Project is managed by DOE's Office of River Protection.

In keeping with the language in the Act, the report is focused on the specific topics of "processing and stabilizing" (called treatment and immobilization) of the tank waste. Currently, DOE is proceeding to acquire waste treatment and immobilization facilities under a cost-plus-incentive fee contract. The DOE had been proceeding to acquire privatized waste treatment and immobilization services. In April 2000, the privatization contractor submitted a proposal that included a sound design and technical solution but an unacceptably high price and open management questions. The DOE quickly and decisively terminated the privatization contract and implemented its contingency plan to complete design and construction of the Waste Treatment and Immobilization Plant (WTP) as a government-owned, contractor-operated facility. A request for proposals was issued in August, proposals were received in October, and the new contract to continue design and construct the WTP was awarded December 11, 2000. Although the privatization contract was terminated, the contractor delivered waste treatment technologies that are robust and have been successfully pilot tested and peer-reviewed. Consequently, the Department's new contract is based on these technologies.

The DOE also has an ambitious technology and research program through the Office of Science and Technology in conjunction with the Office of River Protection. The research efforts include both improving existing technologies and also looking into promising alternative technologies.

This report reflects current project planning; however, it will be updated after the new contractor submits its plans and schedule for the WTP. At that time, the DOE will also be in a better position to extend the plans for the first waste treatment phase to complete the balance of mission.

Background

Approximately 53 million gallons of highly radioactive waste are stored in 177 large underground tanks at the Hanford Site. This waste, which resulted from producing plutonium for the nation's nuclear defense program, has been accumulating at Hanford since 1944. One hundred forty-nine of the tanks are older, single-shell tanks that have exceeded their design life by three decades (Figure 1). Sixty-seven have leaked an estimated one million gallons of waste into the soil beneath the tanks. Radionuclides are moving faster and deeper into the ground than had been previously predicted, and some have reached the groundwater that flows to the Columbia River

Figure 1. Single-Shell Tanks Under Construction at Hanford in 1944

seven miles away. Risks to the environment and the people of the Northwest will increase as more radionuclides reach the groundwater. The highly toxic, highly radioactive tank waste presents a threat to human health and the environment, particularly the Columbia River—the economic lifeline of the region. The only permanent solution to this vexing problem is to immobilize the waste so that the hazardous constituents cannot escape to the environment.

Tank waste cleanup has been regulated under the *Hanford Federal Facility Agreement and Consent Order* since 1989. This Order (known as the Tri-Party Agreement) is an agreement between the U.S. Environmental Protection Agency, Washington State Department of Ecology, and DOE. The Tri-Party Agreement establishes enforceable requirements and milestones for waste cleanup actions. It is a primary driver for the River Protection Project, and any changes to the agreement must go through a public review process and be signed by all three parties.

We have organized our response to address the six topics referenced in Section 3142 of the Act in the order in which they were posed. Those responses follow:

1. *A proposed plan for processing and stabilizing all nuclear waste located in the Hanford Tank Farm.*

River Protection Project Mission

The River Protection Project's primary mission is to retrieve, treat, and immobilize the tank waste. The waste will be removed hydraulically from the tanks and separated into high-level waste (HLW) and low-activity waste (LAW) portions. This separation reduces the amount of HLW, which is more expensive than LAW to immobilize and dispose, by transferring most of the chemicals to the LAW. Both portions will be immobilized in glass (vitrified). The immobilized high-level waste (IHLW) will be stored on site until it can be shipped off-site to the federal geologic repository for disposal. The immobilized low-activity waste (ILAW) will be disposed of on site in an engineered disposal facility.

The waste must also be safely stored until it is retrieved. This includes interim stabilization of the single-shell waste tanks by sending the pumpable liquid waste to the newer double-shell tanks. Monitoring, surveillance, and maintenance activities are performed to validate safe storage conditions and tank integrity.

Upon completing waste immobilization, the tank farm areas and contaminated soils will be deactivated and remediated through a regulatory process called closure, followed by long-term monitoring. These activities are shown in Figure 2.

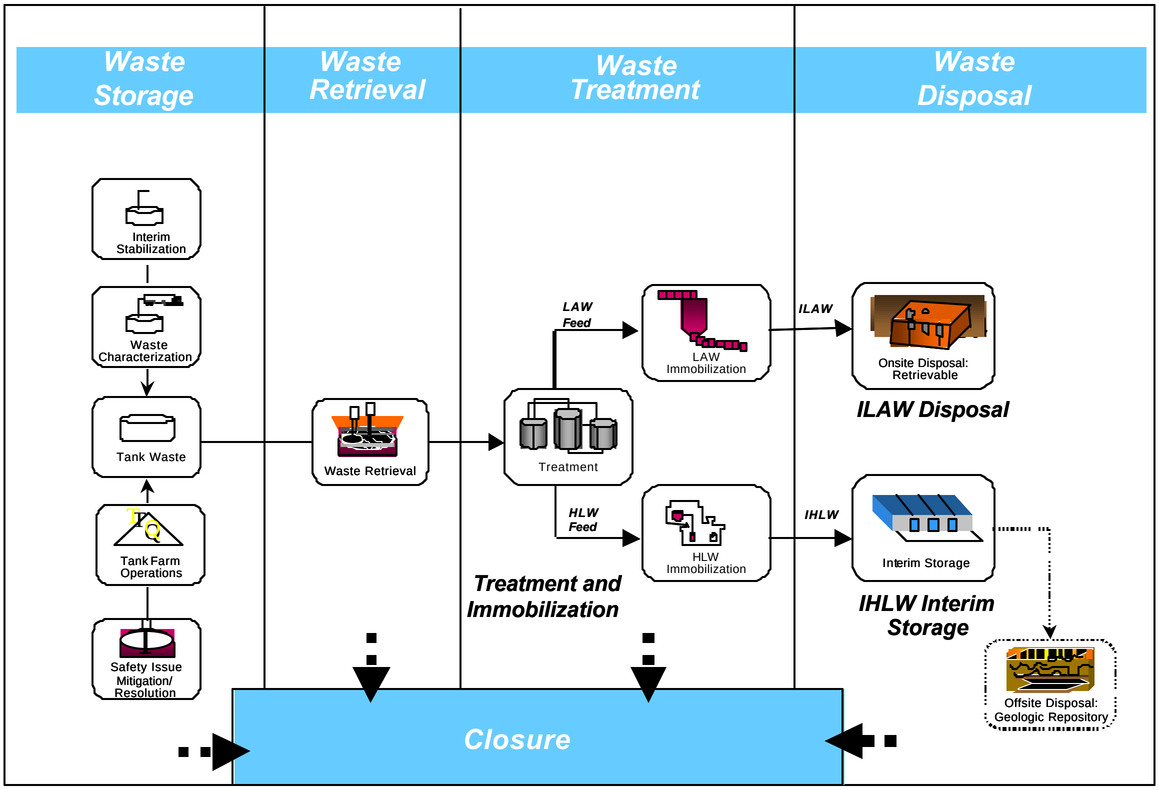

Figure 2. River Protection Project Flow Diagram

The Office of River Protection is also responsible for disposing of 1,933 highly radioactive cesium and strontium capsules from a previous tank waste treatment process. The method for disposing of these capsules has not yet been chosen. Some may be used as radiation sources in other programs. However, for planning purposes it is assumed that during the later stages of the project the cesium and strontium will be blended in with the other high-level tank waste, vitrified, and stored until it can be shipped to the off-site federal geologic repository for disposal.

Desired End State. The River Protection Project will achieve the following desired End State:

- Waste is retrieved from the tanks to the extent necessary to protect human health and the environment.
- The retrieved waste is immobilized, the ILAW is disposed on site and the disposal site closed; the IHLW is shipped to an off-site federal geologic repository for disposal.
- The encapsulated cesium and strontium are treated and shipped to an off-site federal geologic repository for disposal.
- All secondary wastes and effluents are disposed either by the River Protection Project or other Hanford Site programs.
- The tanks and underlying contaminated soils are closed and the other River Protection Project facilities (i.e., the WTP) are deactivated and transferred to the Environmental Restoration Program for disposition.

- Long-term monitoring systems are in place for the closed facilities and disposal sites, and the responsibility for monitoring is transferred to the Hanford Site program responsible for long-term stewardship.

River Protection Project Plan

The plan to treat and immobilize all Hanford tank waste is divided into two phases. A phased implementation was chosen in accordance with the Environmental Impact Statement (EIS) because it meets all regulatory requirements, addresses technical uncertainties, and provides flexibility to accommodate future changes in response to new information and technology development. In Phase 1, 10 percent of the waste by mass and 25 percent by radioactivity will be treated and immobilized. Phase 2, referred to as the Balance of Mission, treats and immobilizes the remainder of the waste. The plan, as shown in Figure 2, is discussed by phase below. As requested in the Act, this report focuses on the plan for treating and immobilizing the waste. However, the other activities that must be accomplished to achieve the desired end state are briefly discussed.

Phase 1 Plan

Waste Storage. The tank waste will be safely stored in the 177 underground tanks until it is retrieved for treatment and disposal. Tank waste safety issues will be resolved, waste will be characterized, the single-shell tanks will be interim-stabilized, and some water will be evaporated to reduce the waste volume. Surveillance, and maintenance of the waste and tanks also will be conducted.

Waste Retrieval. Waste will be retrieved from both single-shell and double-shell tanks, staged in double-shell tanks, and then fed to the WTP. Waste retrieval systems (pipelines, pumps, etc.) will be installed.

Waste Treatment. The WTP will include processes to separate the waste into LAW and HLW portions and to vitrify both portions. The waste from the tanks will be separated into soluble and insoluble portions. Key radionuclides will be removed from the soluble waste so it can be classified as LAW and immobilized (vitrified) for on-site, near-surface disposal. The removed radionuclides will be added to the HLW insoluble portion and vitrified for disposal in an off-site federal geologic repository when it is available.

The vitrified LAW will be poured into cylindrical stainless steel containers 2.3 meters in height and 1.22 meters in diameter. The vitrified HLW will be poured into canisters 4.5 meters in length and 0.61 meters in diameter.

The nominal WTP capacity during Phase 1 will be 30 metric tons of glass per day (MTG/day) of ILAW, 1.5 MTG/day of IHLW. The WTP also will have expansion capability, that will permit doubling its capacity by adding a separate, parallel LAW vitrification facility and a second HLW melter (Figure 3). The HLW vitrification system will be sized such that the capacity can be increased to 6 MTG/day through enhancements to the melters. The WTP is being designed for a 40-year life.

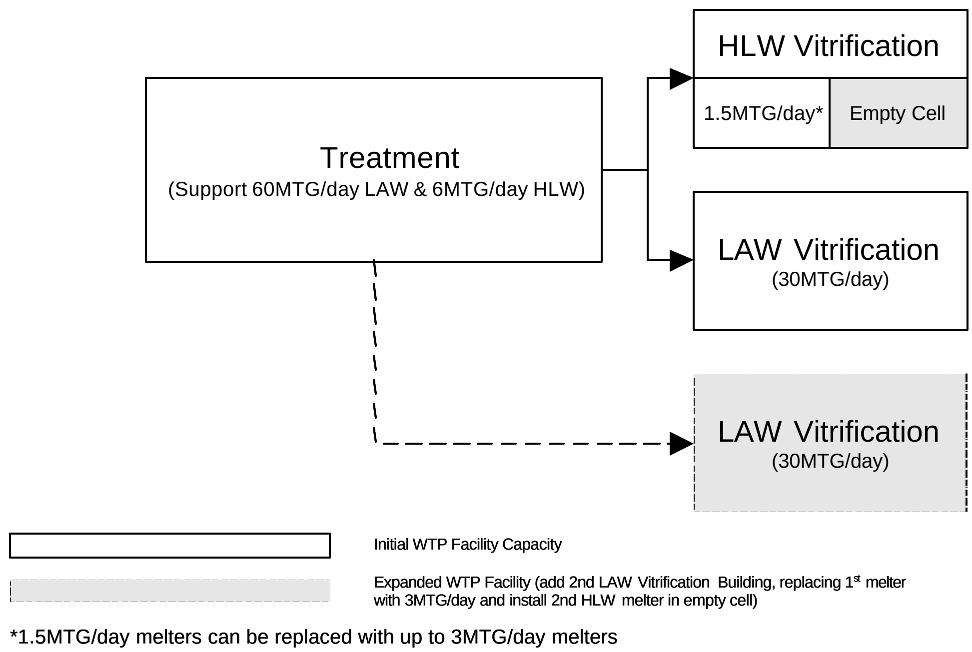

Figure 3. WTP Facility Expansion for Balance of Mission

The WTP capacity and expansion capability was selected to optimize mission achievement, cost, and schedule. DOE made this decision based on optimization studies carried out in 1998[(a)]. Alternatives examined include maintaining current design capacity, decreasing low-activity and HLW treatment capacity, or increasing low-activity and high-level treatment capacity. Life-cycle cost, operability, and capital cost during Phase 1 were considered. The conclusions were:

- The initial WTP LAW treatment capacity with capability to double capacity was the best option based on the unit cost of processing waste and life- cycle costs of building a second plant for Balance of Mission waste processing.
- The expansion to twice the initial plant capacity could meet mission needs within the 40-year design life of the plant, precluding the need to construct a second facility.
- Plants larger than twice the initial capacity would be underutilized due to the difficulty in retrieving waste from the single-shell tanks and would reduce opportunities for technology advancements.

As discussed in the response to Topic 4, the Balance of Mission options rely heavily on the initial capacity and expansion capability of the WTP.

Waste Disposal. The ILAW will be disposed of in new belowground facilities in Hanford's 200 East Area. The facilities will resemble Hanford's mixed low-level waste burial trenches with intrusion-prevention barriers placed on top of the filled trenches.

The two unused cells in Hanford's Canister Storage Building will be outfitted for interim storage of the IHLW canisters produced during Phase 1. The IHLW will be shipped to an off-site federal geologic repository when it is ready to start accepting this waste from Hanford.

(a) Larson, D.E., December 22, 1998, "Optimization of ILAW/IHLW Treatment System and Facility Concepts," RPT-W375-TE00003, Rev. 0, BNFL, Inc., Richland, Washington.

The Phase 1 technical approach is proven and robust. Waste retrieval and transfer operations are currently performed with proven technology. The WTP technology is mature; all operations have been demonstrated on actual waste, from multiple tanks. Radionuclide removal process tests were five times more effective than required, and vitrification pilot plant runs with simulated waste demonstrated capability to achieve at least 150 percent of the WTP design basis. The maturity of the major processes used in the WTP design is shown in Figure 4.

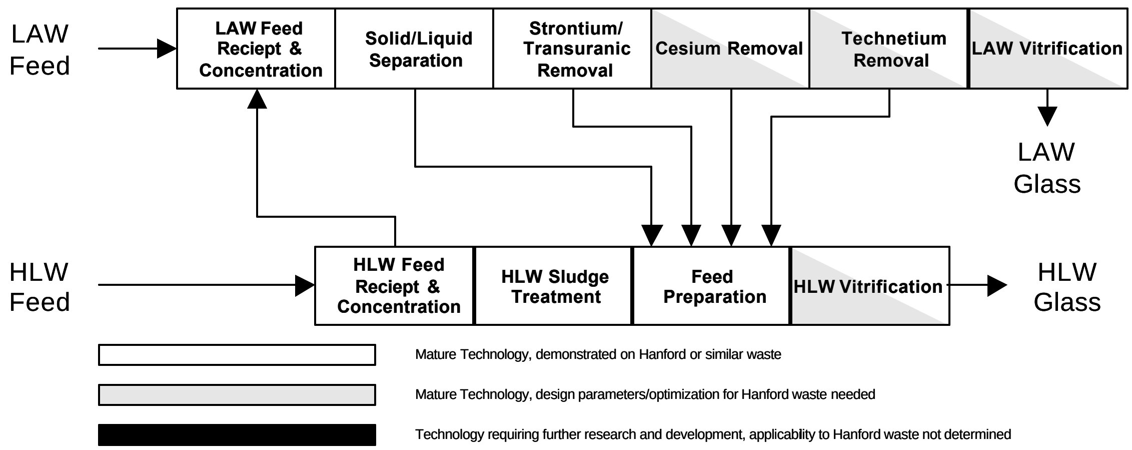

Figure 4. WTP Technology Maturity

Balance of Mission Plan

The River Protection Project plan for the Balance of Mission is to continue the Phase 1 activities with expanded WTP capacities. The scope includes the following:

- Safely storing the tank waste until retrieved
- Retrieving all tank waste necessary to allow tank closure
- Dividing waste into two portions, and removing selected radionuclides from the LAW portion
- Immobilizing both LAW and HLW portions by vitrification
- Disposing ILAW on site, and storing IHLW until it can be shipped to the off-site federal geologic repository for disposal
- Closing the tanks and dispositioning other project facilities.

The existing RPP baseline plan is based on privatized waste retrieval, treatment, and immobilization services. The Balance of Mission plan must now be revised to reflect government-owned treatment and immobilization facilities, and non-privatized contracts for waste retrieval.

The present treatment and immobilization technology can be used to accomplish the Balance of Mission. The challenge is to complete the mission while reducing the project's life-cycle cost. Several factors will influence how the Balance of Mission is planned and conducted. Among those are:

- The double-shell tank capacity available to receive and stage single-shell tank waste for the WTP
- The rate at which waste can be retrieved from the single-shell tanks
- Advancements in technology development
- WTP performance
- Tank closure requirements

Additional knowledge and experience will be gained in Phase 1 before decisions are made on how to proceed with the Balance of Mission during the WTP hot commissioning time frame. The decisions could range from continuing to operate the WTP as configured to increasing its capacity or to adopt another approach. Ways in which the WTP capacity could be increased include attaining better operating efficiencies, exercising the built-in expansion capability (i.e., adding melters and enlarging other processes), implementing improved technologies as they mature, and building additional processing facilities. These are discussed as options in the response to topic 4. Past success in increasing Hanford chemical processing plant capacity through technological advances and operating experience holds promise that these kinds of improvements can be achieved.

2. A proposed schedule for carrying out that proposed plan.

The RPP schedule for carrying out the proposed plan is shown in Figure 5.

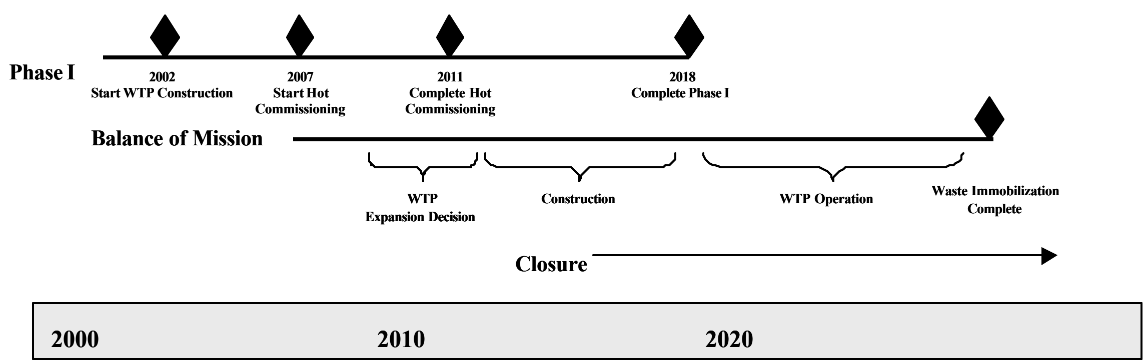

Figure 5. River Protection Project Schedule

Phase 1 will treat and immobilize 10 percent of the Hanford tank waste by mass and 25 percent of the radioactivity by 2018. The Tri-Party Agreement requirement is to complete tank waste treatment and immobilization by the end of 2028. Based on the current project status and the system's physical constraints it appears unlikely now that the project can be completed by that date. The Phase 1 implementation strategy was specifically chosen to provide flexibility to accommodate new information and technology development, and the WTP is being designed to facilitate expansion to substantially increase throughput. Options for carrying out the Balance of Mission are discussed under Topic 4.

3. The total estimated cost of carrying out that proposed plan.

Phase 1

The September 2000 total estimated cost for Phase 1, from fiscal year 2001 through 2018, is as follows:

• WTP design, construction and commissioning	$3.5 billion
• WTP operation 2011 through 2018	1.3
• Safe waste storage and characterization	4.1
• Waste retrieval	2.4
• Immobilized waste storage and disposal	1.8
• Other project costs (WTP fee, contingency, and support costs)	1.8
Total (Fiscal Year 2000 dollars, unescalated)	$15 billion (rounded)

The WTP estimated cost of $3.5 billion is the September 2000 target cost estimate for completing design, constructing, and commissioning. This estimate is based on the Government Fair Cost Estimate of the privatization contractor's design and cost estimates completed in April 2000.

There will be River Protection Project costs in addition to the $15 billion listed above during 2001 through 2018, as Balance of Mission preparations will be going on in parallel. Those costs are included in the life-cycle cost estimate discussed below.

Balance of Mission

The Balance of Mission will disposition the remaining tank waste and includes safe storage of waste in tanks; waste retrieval, treatment, and immobilization; immobilized waste storage and disposal; tank closure; and disposition of facilities. Current estimates for this segment of the project were based on the privatization concept for both retrieval and treatment systems and are, therefore, outdated. Based on those estimates, the cost for the Balance of Mission is in the range of $20 to $25 billion (Fiscal Year 2000 dollars, unescalated) over the next 40 years. The River Protection Project life-cycle estimate (Phase 1 plus Balance of Mission) is $35 to $40 billion. This cost estimate is based on existing estimates and is comparable to, but higher than, the 1996 EIS estimates of $25 to $33 billion (in 1996 dollars, unescalated; see Table 1 accompanying the response to Topic 4).

4. A description of any alternative options to that proposed plan and a description of the costs and benefits of each such option.

Tank Waste Remediation System EIS. The current plan for processing and stabilizing Hanford's tank waste implements the "Phased Implementation Alternative" evaluated in the EIS.[a] This alternative was selected for implementation in the Record of Decision because "it provides a balance among short- and long-term environmental impacts, meets all regulatory

(a) *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, DOE/EIS-0189, U.S. Department of Energy and Washington State Department of Ecology, August 1996.

requirements, addresses the technical uncertainties associated with remediation, and provides the flexibility necessary to accommodate future changes in the remediation plans in response to new information and technology development."[(a)] The decision on a plan of action for disposition of the cesium/strontium capsules was deferred until additional information is available.

The alternatives evaluated in the EIS represent a range of reasonable alternatives for managing and disposing of the tank waste and bound the potential environmental impacts. These alternatives ranged from leaving all of the waste in the tanks to retrieving essentially all of the waste, and from doing minimal to extensive treatment and processing of the retrieved waste. Treatment and processing alternatives evaluated included vitrification, calcination, and other waste forms and varying degrees of HLW and LAW separation. A summary of the costs and benefits of each of the evaluated alternatives is provided in Table 1. The Office of River Protection's current plan of Phase 1 treating 10 percent of the waste and a subsequent phase to treat the 90 percent Balance of Mission is bounded by the EIS range of alternatives. The current plan meets all waste disposal laws, regulations, and policies, has low technical risk compared to the other alternatives, and does not contribute to any restrictions on future use of the Hanford Site groundwater and Columbia River shoreline. Other long- and short-term environmental and health effects of each of the alternatives are discussed in the EIS.

(a) *Record of Decision for the Tank Waste Remediation System, Hanford Site, Richland, Washington*, U.S. Department of Energy, February 1997.

Table 1. Comparison of Costs and Benefits of Alternatives Evaluated in the 1996 Environmental Impact Statement (Costs in 1996 Dollars, Unescalated)

Extent of Waste Retrieval from Tanks	Waste Treatment and Processing Alternatives	Meets Waste Disposal Laws, Regulations, and Policy[1]	Degree of Technical Uncertainty[2]	Potential Resource Use Restrictions[3,4]	Cost Range (Excluding High-Level Waste Disposal Costs)[5]
None	None	No	Low	Use of Site Groundwater Use of River Shoreline	$13-23 Billion
Minimal (liquid waste only)	Fill tanks with gravel	No	Low	Use of Site Groundwater Use of River Shoreline	$7-9 Billion
	Vitrification of waste and tanks in place	No	High	No Restrictions	$16-27 Billion
Partial (only tanks having highest potential long-term groundwater impacts)	Separate retrieved waste into high-level and LAW streams and vitrify both	No	Moderate	Use of Site Groundwater	$14-23 Billion
Extensive (99% of all waste)	No separation of waste into waste streams; vitrification of all waste	Yes	Moderate	No Restrictions	$23-28 Billion (Does not include over $30 Billion in Repository cost)
	No separation of waste into waste streams; calcination of all waste	No	Moderate	No Restrictions	$21-26 Billion (Does not include over $30 Billion in Repository cost)
	Separation of waste into high-level and LAW streams; vitrification of all waste	Yes	Moderate to High	No Restrictions	$24-37 Billion
	Current Plan Same as above except phased implementation rather than full implementation immediately	Yes	Low	No Restrictions	$25-33 Billion[6]

[1] "No" means the alternative does not meet all applicable laws, regulations, and policies. A change in policy, waiver from a regulation, and/or a change in federal or state law would be required to implement this alternative.
[2] A measure of the uncertainty involved with effectively implementing the alternative relative to the other alternatives. High uncertainty means the risk of failure is higher than other alternatives.
[3] All alternatives would include surface restrictions of the area within the tank farms.
[4] Potential restrictions are based on levels of contamination from tank waste. Additional restrictions may be necessary due to other Site conditions.
[5] Cost ranges are in 1996 dollars and are provided to reflect the uncertainties with the conceptual nature of the designs and technologies involved. Costs for disposal of the HLW at the repository are not included.
[6] The response to Topic 3 provides the most current estimate (1996) for implementing the phased alternative or Proposed Plan.

Options for Balance of Mission. The phased approach to retrieve and immobilize the Hanford tank wastes recognizes that technical uncertainties exist for successfully completing the cleanup mission. Additionally, DOE recognizes its responsibility to reduce risk, decrease cost, and accelerate completion of the cleanup mission. As discussed earlier, DOE is actively identifying and evaluating options to improve the current plan. Options being investigated include:

- Increasing WTP throughput by addressing rate-limiting steps and increasing operating efficiency
- Increasing waste loading in the immobilized waste products
- Inserting new or improved technology
- Implementing the expansion features being designed into the Phase 1 WTP
- Extending the useful life of the WTP
- Constructing additional waste treatment facilities.

All of these options use the Phase 1 WTP, which has an operating design life of 40 years. Proposed expansions to the WTP at the end of Phase 1, which would nominally double the capacity, were illustrated earlier in Figure 3.

Another option being considered is a risk-based approach to waste retrieval and tank closure. This approach would retrieve and treat waste from the highest environmental risk tanks first, thus lowering the overall health risk to the public sooner. As time proceeds, each tank and its contents would be evaluated to determine the extent its waste would be retrieved. This could result in less waste being treated. The current Tri-Party Agreement requirement is to remove 99 percent of the waste from all of the tanks. Implementing an approach that would change that requirement would require regulatory approval.

The potential impact of all of these options being considered is illustrated in Figure 6, which shows the range of possibilities for completing the waste treatment and immobilization mission within the operating life of the WTP. Figure 6 illustrates how much of the waste could be processed over time depending on the capacity and efficiency of the WTP. The upper dotted line represents current cleanup requirements. With an assumed Phase 1 operating efficiency of 48 percent, increased to 60 percent for the balance of the mission to reflect operating experience (a combination of greater throughput and reduced downtime), the amount of waste processed over time is shown by the lower line in Figure 6.

Expanding the WTP to double the capacity would treat 100 percent of the retrieved waste within its design life. The upper line in Figure 6 illustrates what could be accomplished by quadrupling overall plant capacity, which would require, without efficiency or technology improvements, building additional treatment and vitrification facilities beyond those indicated in Figure 3.

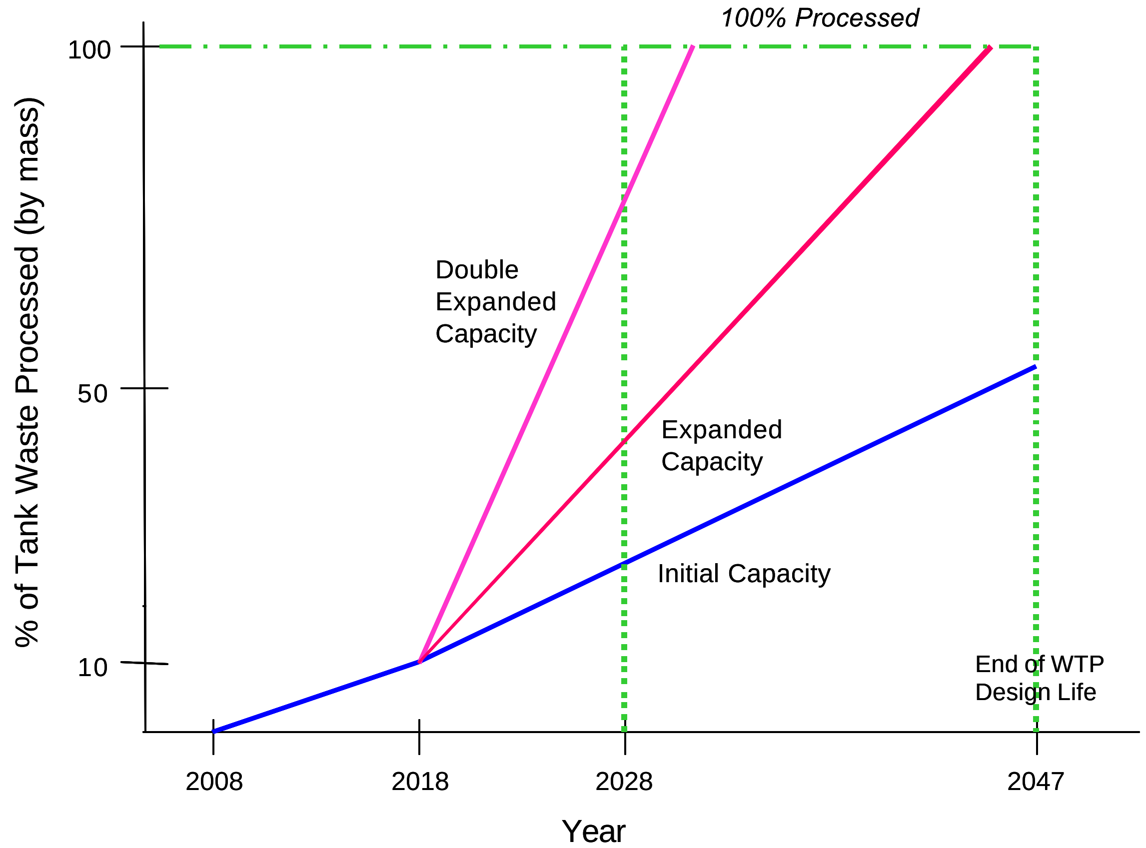

Figure 6. Tank Waste Processing for Different WTP Capacities

The WTP capacity needed and/or the time to complete waste processing would be significantly influenced if a risk-based approach to waste retrieval reduces the amount of waste that has to be removed from the tanks and processed. Moreover, the time could be reduced if process/plant efficiencies or new technologies could be incorporated into the WTP.

The DOE has successfully demonstrated the technologies required to carry out Phase 1 processing and will be making parallel investments during Phase 1 to take advantage of any emerging technologies that can be incorporated into the WTP. The Office of River Protection is working jointly with the DOE Environmental Management Office of Science and Technology in a sustained effort to accelerate progress and reduce technical risk. Areas being addressed include not only vitrification and melter technology but advanced separations processes and methods for treating the River Protection Project cesium and strontium capsules. In particular, separations research could result in a reduction in the amount of waste requiring processing by the WTP, which could in effect increase the processing rates shown in Figure 6.

5. A description of the volumes and characteristics of any wastes or materials that are not to be treated during Phase 1(B) of the project.

Hanford tank waste consists of approximately 192 million curies[(a)] in 200,000m^3 (53 million gallons) of highly radioactive and mixed waste stored in 177 underground storage tanks. The tank waste includes solids (sludge), liquids (supernatant), and salt cake (precipitated salts that are soluble in water). Two types of waste feed streams will be delivered to the WTP, a low-activity waste feed and a high-level waste feed. The low-activity waste feed consists of the tank waste liquids and dissolved salt cake and contains the bulk of the tank waste chemicals and certain radionuclides, depending on the waste source (e.g., cesium, technetium, strontium, and transuranics). The low-activity waste feed may also contain a small quantity (<2 weight percent) of entrained solids. The high-level waste feed comprises primarily insoluble compounds and the long half-life radionuclides. Some liquids will accompany the high-level waste feed during delivery to the WTP.

The WTP is designed to treat waste feed that meets three low-activity waste feed envelopes and one high-level waste feed envelope. The feed envelopes represent a range of upper concentration limits. All Phase 1 and approximately 90 percent of Balance of Mission tank waste feeds are expected to fall within the feed envelope definitions. The remainder of the waste including possibly the cesium and strontium capsules can meet processing requirements primarily through blending and waste loading in the immobilized product. All Phase 1 waste feed sources have been characterized and meet the processing requirements.

The experience gained during Phase 1 should position the Office of River Protection well for beginning Balance of Mission processing. The DOE will be conducting a technology development effort in parallel with Phase 1 to optimize processing of the remaining waste.

Waste Volumes. The volume of waste stored in the177 tanks is estimated to be 200,000 m^3 (53 million gallons). Approximately 17 percent of the stored tank waste volume will be processed in Phase 1. The volume of waste feed actually delivered to the WTP will be greater than the stored waste because water will be added to dissolve and mobilize some of the wastes.

While the volume of the waste that may be immobilized from the cesium and strontium capsules is small relative to the tank waste feed volume, the capsules' contain approximately 130 million curies (decayed to December 31, 2000), 40 percent of the total radioactivity to be disposed of by the RPP.

Waste Characteristics. The waste in Hanford's storage tanks consists primarily of sodium hydroxide, sodium nitrate, sodium nitrite, sodium aluminate, sodium phosphate, and water. Numerous other constituents are present in smaller quantities including species such as sulfate, iron, zirconium, fluoride, chloride, potassium, manganese, nickel, chromium, radionuclides and some organic complexants.[(b)] The organic components of the waste are a very small fraction of the overall waste mass.

(a) Kirkbride, et. Al. 2000, *Tank Farm Contractor Operation and Utilization Plan*, HNF-SD-WM-SP-012, Rev. 2, April 19,2000, CH2M Hill Hanford Group, Inc., Richland, Washington. Inventory includes daughters and has been decayed to December 31, 2000.
(b) Allen 1976, *Estimated Inventory of Chemicals Added to Underground Waste Tanks, 1944 through 1975*, ARH-CD-610B, G. K. Allen, Atlantic Richfield Hanford Company, Richland, Washington, March 1976.

The Office of River Protection has performed extensive characterization of the wastes that will be Phase 1 feed to the WTP. Waste previously characterized for safe storage has been recharacterized specifically for retrieval, feed delivery, treatment, immobilization, and disposal. Estimated inventories for all tank waste based on sampling and process knowledge include 25 chemicals and 46 isotopes. Those analytes represent over 99 percent of the waste mass and over 99 percent of the radioactivity. The estimated inventories are continually being improved as new sample data are received and waste is transferred, so the estimates of tank waste compositions are expected to change somewhat over time. Treatment and immobilization process tests have been conducted on multiple tanks and waste types. The balance of the Phase 1 waste will be subjected to confirmatory processing testing in the early stages of Phase 1 by the WTP contractor, who will be carrying out an extensive testing program.

During Phase 1, approximately 5000 of the 48,000 metric tons of sodium (MT Na) stored in the tanks will be processed as low-activity waste, and sufficient solids will be processed to produce approximately 600 of the total estimated 12,200 canisters of immobilized high-level waste. At least 25 percent of the tank farm waste radioactivity will be processed in Phase 1. Balance of Mission processing will include the treatment of the remaining tank waste and may also include the cesium and strontium capsules.

A summary of the total and Balance of Mission waste characteristics is provided in Table 2. The Balance of Mission waste feed generally will be similar to that processed in Phase 1, with an expected variability in some of the chemicals and isotopes. The variability can be addressed using techniques such as blending wastes to minimize the amount of glass to be produced, or increasing the proportion of glass formers to waste to accommodate chemicals that have glass processing limits.

Some wastes may be special cases. For example, the cesium and strontium capsule contents must be processed separately and then blended before being made into glass. A small inventory of separate organic phase waste contained in one tank, approximately 4,500 gallons, may require segregation and separate processing and disposition of the organic materials. Current Phase 1 technologies will work, but advanced technologies may be considered for improving processing waste containing components of limited glass solubility and trace concentrations of noble metals.

Table 2. Summary of Balance of Mission Tank Waste Characteristics

Waste Characteristic	Total in Double-Shell Tanks and Single-Shell Tanks	Estimated Fraction Remaining for Balance of Mission
Sodium (Na), Metric Tons	48,000 Metric Tons	90%
Radioactivity, Curies	192 million Curies	75%
Cesium-137[(a)]	91 million Curies	60%
Strontium-90[(a)]	98 million Curies	63%
Sludge	13 million gallons	95%
Supernatant	16 million gallons	60%
Salt Cake	24 million gallons	94%

(a) Some radionuclides have a relatively short half-life (the period in which half of the radioactivity decays), therefore, the date to which the activity (curies) applies is often provided as a reference point to the reader. Cesium-137 and strontium-90 are two examples of radionuclides with short half-lifes, 30 and 28.5 years, respectively. Inventories include daughters decayed to December 31, 2000. Inventories do not include cesium and strontium capsules.

6. A plan for developing, demonstrating, and implementing advanced vitrification system technologies that can be used to treat and stabilize any out-of-specification wastes or materials (such as polychlorinated biphenyls) that cannot be treated and stabilized with the technologies that are to be used during Phase 1(B) of the project.

Since the inception of the Tanks Waste Remediation System Project at Hanford, the DOE has recognized that private industry can provide technological solutions to treat the tank wastes economically and safely. Beginning in 1994, DOE has supported technology assessments and demonstrations of candidate HLW and LAW vitrification processes.[a,b] From this earlier work, a significant tenet of the River Protection Project was founded: to look to the commercial sector for technological solutions. Through the solicitation process, two teams representing the best available technologies were selected in 1997 and evaluated in detail. The Project has since progressed from the technology assessment phase to the implementation phase. Although the future will always hold the promise of improvements in technology, the Office of River Protection must move forward with this vital mission. Flexibility is being maintained for incorporating technology advancements as the project progresses. However, the base separations and vitrification technology have been selected and demonstrated to meet the Phase 1 requirements for waste treatment.

There are no out-of-specification wastes or materials that cannot be treated and stabilized with the Phase 1(B) vitrification technology. If polychlorinated biphenyls are found to be present, they can be treated using the vitrification technology already selected for Phase 1. Depending on the performance of the combined HLW treatment and control technology processes in treating polychlorinated biphenyls some evaluation of the melter off-gas treatment system may be required. Additional, secondary waste systems within the plant, such as solid waste management systems, may have additional Administration or Technical requirements imposed on them. If the waste treatment plant's secondary waste do not meet release requirements or the accepting facility's requirements. However, at present, this is not believed to be the case.

The current pretreatment and vitrification technologies are sufficient for Phase 1 wastes, although some challenges (for peak WTP performance) remain.[c] Even for Balance of Mission requirements, there are no out-of-specification wastes that cannot be vitrified with the melter technology. However, in some cases reduced waste loadings and a resulting increase in glass canister production will occur. It is estimated that the current technologies will produce 12,200 canisters of IHLW and 219,000 cubic meters of ILAW. Improvements that could reduce the amount of vitrified waste include additional blending options, developing advanced chemical separations and sludge washing techniques, and improved vitrification technology. For vitrification, the primary challenges are to increase waste loading and increase melter production capacity without significantly increasing melter size. To address these challenges, DOE has begun work to develop, demonstrate, and if justified, will implement advanced vitrification system technologies. This work is summarized in the following sections.

(a) Calmus, R. B. 1995. *High-Level Waste Melter Alternatives Assessment Report*. WHC-EP-0847. Westinghouse Hanford Company. Richland, WA 99352.
(b) Wilson, C. N. 1996. *Melter System Technology Testing for Hanford Site Low-Level Tank Waste Vitrification*. In Spectrum '96. WHC-SA-3092-FP. Westinghouse Hanford Company, Richland, WA 99352.
(c) Harmon, H. D. et. al. 1999. Technical Alternatives to Reduce Risk in the Hanford Tank Waste Remediation System Phase 1 Privatization Project. DOE-EM-0493, U.S. Department of Energy.

Low-Activity Waste Vitrification Issues. For the Hanford LAW glasses, optimized sodium-aluminum-silicate glass systems can achieve a maximum sodium oxide concentration of approximately 20 weight percent. This concentration can be achieved within the temperature capabilities of the Phase 1 melter technology. A number of the Hanford tanks contain so-called "minor constituents" that are problematic in that they are soluble in silicate-based glasses at just fractions of a percent. The critical minor constituents are chromium, sulfur, phosphorous, fluorine, and chlorine. Of these, sulfur has the greatest potential impact on Balance of Mission. It is estimated that approximately 25 percent more ILAW glass will be produced if advances are not achieved in sulfate removal, mitigation, or glass solubility.

Advanced Low-Activity Waste Vitrification Technology Planning. The Office of River Protection will continue to fund and support research and development activities to maximize waste loading in the presence of sulfate. The new WTP contractor will make research and technology investments as part of Phase 1 to gain additional knowledge and understanding of sulfur solubility as a function of glass properties. Pilot-plant testing and supporting technology work will further define the baseline and improvements will be pursued if necessary, to ensure target goals for reliability, service life, and production rate will be met.

The DOE Environmental Management Office of Science and Technology is responsible for longer-term, higher-impact technology solutions. The Office of River Protection is requesting the Office of Science and Technology to continue a program on sulfate incorporation issues. Research areas being considered include glass formulation studies, methods to increase sulfate incorporation in glass, and methods to detect sulfate salt accumulations in a melter.

The Office of River Protection is also requesting the Office of Science and Technology to investigate alternative or advanced technologies and waste forms to determine their ability to significantly reduce life-cycle waste immobilization and disposal costs. Evaluations and demonstrations will be performed on LAW glasses that can achieve higher waste loadings or durable crystalline phases. Results from this work are expected to benefit primarily the Balance of Mission. However, if significant early progress is made, the results may also benefit Phase 1.

High-Level Waste Vitrification Issues. Borosilicate glass was selected in 1982 as the preferred waste form for defense HLW disposal in a federal geologic repository.[(a)] The acceptability of borosilicate glass for Hanford HLW was also reviewed in 1990.[(b)] Borosilicate glass will be used as the HLW form in Phase 1 and likely in the Balance of Mission. Relatively high levels of iron, aluminum, chrome/nickel, zirconium, and to a limited extent phosphate, individually or in combination, restrict waste loadings in Hanford HLW glasses melted at 1,150 °C. Options for reducing HLW and glass production include:

- waste feed blending
- enhanced waste separations
- producing alternate glasses tailored for specific waste tanks, e.g., high phosphate
- producing borosilicate glasses at higher temperatures, e.g., 1,250°C to 1,400°C
- adopting improved or new vitrification technology that is tolerant of crystals in the glass and capable of transferring them from the melter to the canister.

(a) U. S. DOE. 1982. Environmental Assessment-Waste Form Selection for SRP High-Level Waste, US DOE Report DOE/EA 0179, Washington, DC
(b) U. S. DOE. 1990. Evaluation and Selection of Borosilicate Glass as the Waste Form for Hanford High-Level Radioactive Waste, US DOE Report DOE/RL-90-27, Rev. 1, Richland, Washington.

A second issue is the presence of relatively minor concentrations of noble metals in the waste. Although present at levels of just fractions of a weight percent, they are essentially insoluble in glass. If sufficient noble metals accumulate in a melter, it will have to be replaced earlier than otherwise necessary. Vitrification melter designs or operating methods that prevent noble metals accumulation would mitigate noble metals effects.

Advanced High-Level Waste Vitrification Technology Planning. The WTP contractor will be responsible for assessing and adopting incremental waste form development and technology advancements in Phase 1. However, for Balance of Mission, significant advances in HLW processing can be gained by improved glass waste loading, producing glass or glass and crystalline waste forms tailored for specific tank problems, and improved or alternative vitrification technology. The DOE activities in these areas are summarized below.

The Office of Science and Technology is conducting a multi-laboratory effort to achieve higher waste loadings in Hanford borosilicate glass systems and is working to better understand the behavior of noble metal precipitates in molten glass, with the intent of devising methods for periodically or continuously suspending them so that they can be discharged from an operating melter. The Office of Science and Technology also initiated evaluation and demonstration of a novel vitrification technology. Called the Advanced Vitrification System, the waste form and batch processing technology are being proposed as alternatives to borosilicate glass and the current melter technology.

Beginning this year, the Office of Science and Technology has initiated three new activities with the Office of River Protection's support. A team of national experts has been chartered to conduct a review of advanced HLW melter and waste product alternatives that could achieve major cost reductions with acceptable long-term risks. The approach is to develop an understanding of waste form performance requirements and then to identify the waste forms and melter concepts that would meet those requirements. If the results conclude that a cost benefit is achievable through improved waste loadings, waste formulations, and corresponding melter technologies, recommendations will be made to follow-up research and development to confirm the study assumptions and conclusions and to pursue the recommended path forward for advanced melter development.

The second effort is to perform a detailed evaluation of an alternative vitrification technology. Called the induction-heated, cold-crucible melter, it can operate at temperatures higher than the current WTP melter technology and permits higher waste loadings. The induction-heated, cold-crucible melter also does not have electrodes or refractory components contacting the molten glass. Therefore, melter disposal and replacement have the potential to be more economical. The Office of Science and Technology plans to enter into technology assessment agreements with Russian and French developers, under which DOE will be able to examine the technology and assess its capabilities.

Third, the Office of River Protection is requesting the Office of Science and Technology to proceed to execute the recommendations of the expert panel's waste form and melter technology review report, assuming they are favorable. Alternative or advanced waste forms and technologies will be evaluated to determine their ability to significantly reduce the project life-cycle costs. Results from this work are expected to benefit primarily the Balance of Mission.

Finally, as part of the Environmental Management Science Program, DOE is investing in basic science research in the areas of glass science and performance. The program is funded through the Office of Science and Technology and is co-managed by the Office of Science and

Technology and the DOE Office of Science. Research into alternative glass systems such as iron-phosphate glasses has been supported for several years. A second project has been investigating crystalline silicotitanate systems for use in waste fixation. A third project, due to be completed this year, is modeling the formation and settling behavior of crystal phases in melters. Several Environmental Management Science Program projects studying the long-term performance of glass waste forms to support disposal system performance assessments have provided insights to help formulate better performing glasses. This program is also initiating a new call in fiscal year 2001 for improvements in separations and immobilization technologies. The Office of Science and Technology, through the Tanks Focus Area, is initiating a new solicitation in fiscal year 2001 in the applied research area on advanced melter and glass formulation (waste loading) improvements, which should result in additional research and development beneficial to the River Protection Project.

Conclusion

The Office of River Protection has embarked on a plan that will safely remediate the Hanford tank waste. At this time, DOE is focused on initiating construction of the WTP to be able to start hot operation in 2007 and carry out Phase 1 of the project. The Office of River Protection remains committed to completing treatment of all the waste and has begun to analyze options for the best way to carry out the Balance of Mission. A baseline for completing the Balance of Mission will be developed, including identification of high-payback science and technology investments. As we proceed with Phase 1 we will gain experience and will aggressively pursue ways to reduce risk, improve performance, and reduce project costs.